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Physiological Daily Inhalation Rates for Free-Living Individuals Aged 1 Month to 96 Years, Using Data from Doubly Labeled Water Measurements: A Proposal for Air Quality Criteria, Standard Calculations and Health Risk Assessment

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ABSTRACT

Reported disappearance rates of oral doses of doubly labeled water (^2H_2O and $H_2^{18}O$) in urine, monitored by gas-isotope-ratio mass spectrometry for an aggregate period of over 30,000 days and completed with indirect calorimetry and nutritional balance measurements, have been used to determine physiological daily inhalation rates for 2210 individuals aged 3 weeks to 96 years. Rates in m^3/kg-day for healthy normal-weight individuals ($n = 1252$) were higher by 6 to 21% compared to their overweight/obese counterparts ($n = 679$). Rates for healthy normal-weight males and females drop by about 66 to 75% within the course of a lifetime. Infants and children between the age of 3 weeks to less than 7 years inhale 1.6 to 4.3 times more air (0.395 ± 0.048 to 0.739 ± 0.071 m^3/kg-day, mean ± S.D., $n = 581$) than adults aged

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Abbreviations: BEE: basal energy expenditure (BMR expressed on a 24-hour basis), BMI: body mass index, BMR: basal metabolic rate (punctual measurement), DLW: doubly labeled water, DMET: daily metabolic equivalent (TDER/BEE ratio), ECG: stored daily energy cost for growth, H: oxygen uptake factor, volume of 0.21 L of oxygen (at standard temperature and pressure, dry air) consumed to produce 1 kcal of energy expended, MET: metabolic equivalent (BMR multiplier), TDEE: total daily energy expenditure, TDER: total daily energy requirement (summation of ECG and TDEE), V_E: minute volume rate, VO_2: oxygen uptake rate, VQ: ventilatory equivalent ratio (V_E at body temperature pressure saturation/VO_2 at standard temperature and pressure, dry air)

23 to 96 years (0.172 ± 0.037 to 0.247 ± 0.039 m^3/kg-day, n = 388). The 99th percentile rate of 0.725 m^3/kg-day based on measurements for boys aged 2.6 to less than 6 months is recommended for air quality criteria and standard calculation for non-carcinogenic compounds pertaining to individuals of any age or gender (normality confirmed using the Shapiro-Wilk test, $p \geq 0.05$). This rate is 2.5-fold more protective than the daily inhalation estimate of 0.286 m^3/kg-day published by the Federal Register in 1980 (i.e., 20 m^3/day for a 70-kg adult). It ensures that very few newborns aged 1 month and younger, less than 1% of infants aged 2.6 to less than 6 months and of course no older individuals up to 96 years of age inhale more toxic chemicals than associated safe doses which are not anticipated to result in any adverse effects in humans, when air concentration reaches the resulting air quality criteria and standard values. This rate is also protective for underweight, overweight, and obese individuals. Finally, as far as newborns are concerned, a rate of 0.956 m^3/kg-day based on the 99th percentile estimates is recommended for short-term criteria and standard calculations for toxic chemicals that yield adverse effects over instantaneous to short-term duration.

Key Words: daily inhalation rates, distribution percentiles, probability density functions, air quality criteria, standard value, risk assessment, doubly labeled water.

INTRODUCTION

Human short- and long-term adverse health effects are well known to occur as a result of exposure to air pollutants (Abbey *et al.* 1993; Burnett *et al.* 1994, 1997a, b, c; Coyle *et al.* 2003; Ghio and Devlin 2001; Godleski *et al.* 2000; Hajat *et al.* 2001; Heinrich, *et al.* 1999; Liu *et al.* 2003; Neher and Koenig 1994; Pope 2000; Schwartz *et al.* 1991; Tolbert *et al.* 2000; Ware *et al.* 1993; Yang *et al.* 2003). Several studies have also provided persuasive evidences that air pollution is directly linked to mortality (Abbey *et al.* 1999; Burnett *et al.* 1998a, b, 2000, 2001; Dockery *et al.* 1993; Godleski *et al.* 2000; Loomis *et al.* 1999; Pope *et al.* 2002, 2004; Samet *et al.* 2000; Thurston and Ito 2001; Villeneuve *et al.* 2003; Ware 2000). Chronic adverse health effects have been reported even at relatively low levels of particulate air pollutants currently measured in urban areas (Bascom *et al.* 1996a, b). Precise daily inhalation rates are essential in health risk assessment, because lung ventilation controls the transportation of air pollutants to the respiratory tract and influences their deposition onto surfaces of the conducting airways and pulmonary region, and ultimately determine the inhaled doses of air pollutants (Polgar and Weng 1979). Although numerous lung function measurements, notably minute ventilation rates, have been taken from subjects performing various tasks, there have been no experimental measurements of the physiological 24-hour inhalation rates of free-living people (Allan and Richardson 1998; Layton 1993). In the United States, the value of 20 m^3/day for a 70-kg adult based on an 8-hour work day has been adopted as a standard inhalation rate for humans (Federal Register 1980). This value is widely used to determine the inhaled dose for a given air pollutant for adults and it is notably used in the default approach for the determination of reference concentrations (Benson *et al.* 2002; Paustenbach 2001). In Canada, a daily inhalation rate of 23 m^3/day was derived from the inhalation data determined by the International Commission on Radiological Protection (Health Canada 1994; Snyder *et al.* 1975).

Respiratory symptoms and lung function changes are the most common effects resulting from air pollution, particularly in children (Braun-Fahrländer *et al.* 1997; Brunekreef *et al.* 1997; Chen *et al.* 1998; Dockery *et al.* 1989, 1996; Hoek *et al.* 1990; Hoelzer *et al.* 2002; Jedrychowski and Flak 1998; Peters *et al.* 1999; Wjst *et al.* 1993). For instance, ambient concentrations of ozone were positively associated with respiratory hospital admission among young children and the elderly in Vancouver, British Columbia (Yang *et al.* 2003). Notably, air pollution was positively associated with the prevalence of asthma in children and adults (Gielen *et al.* 1997; Guo *et al.* 1999; Hales *et al.* 1998; Norris *et al.* 1999; Peters *et al.* 1997; Segala *et al.* 1998; Sheppard *et al.* 1999; Studnicka *et al.* 1997; Sunyer *et al.* 1997; Tolbert *et al.* 2000). Functional signs of airway obstruction and obstructive pulmonary disease have also been linked to air pollution (Sunyer *et al.* 1991; Zapletal *et al.* 1976). In order to estimate intake and uptake variations of air pollutants as a function of age from infancy to adulthood, age dependent daily inhalation rates have rapidly become essential in health risk assessment. Two types of approaches have been developed for this purpose: time-activity-ventilation and metabolic energy conversion (Allan and Richardson 1998; Finley *et al.* 1994; Layton 1993; Roy and Courtay 1991; Versar 1989). In the first approach, inhalation rates are estimated by taking into account the cumulative minute ventilation rates (in L/min) associated with activities or levels of activity and their duration throughout the day (e.g., sleeping, walking). In the second approach, inhalation estimates are based on the daily food-energy intake or cumulative energy expenditure (in kcal/min) required to support activities or levels of activity throughout the day. A critical review of relevant biases and magnitude of under- and overestimations for each approach appears in a companion article by Brochu *et al.* (2006a), where it is shown that daily inhalation rates resulting from such bases are partially biased, notably by lack of data and adequate statistical values for some age/sex groups and activity levels.

Monte Carlo simulations have been used by Allan (1995) to estimate 24-hour inhalation rate probability density functions for use in health risk assessment by the Health Protection Branch of Health Canada (Allan and Richardson 1998). These Monte Carlo simulations as well as those conducted by Finley *et al.* (1994) to estimate statistical distributions for daily inhalation rates do not eliminate the biases from the preliminary input breathing parameters, as they include them in the statistical process (Brochu *et al.* 2006a). In fact, accuracy of daily inhalation estimates has been improved by conversion of daily food-energy intakes from dietary surveys as done by Layton (1993). The resulting inhalation values consist of single values (point estimates) for each age group without standard deviations and percentile distributions associated to each sub-group of individuals. Yet, the daily inhalation rates for individuals aged less than 1 year up to 18 years were recommended in United States as long-term inhalation rates and for long-term dose assessment of air pollutants (USEPA 1997; Versar, 2000). Many other biases are present, in particular in self-reported dietary intakes during food surveys (Bandini *et al.* 1990a, 1990b, 2003; Bellisle 2001; Black *et al.* 1993; Johnson 2000; Livingston *et al.* 1990; Subar *et al.* 2003; Trabulsi and Schoeller 2001; Torun *et al.* 1996). Moreover, energy loss in stool, intestinal gases, and urine has not been subtracted from dietary energy intakes reported by Layton (1993) before converting metabolic energy into daily inhalation rates (IDECG 1990; Lucas 1989).

Daily inhalation rates (in m^3/day and/or m^3/kg-day) are notably used to adjust data from human occupational and laboratory animal exposure assessments via inhalation of toxic compounds for the determination of some reference concentrations (RfCs) and many criteria/guideline values (e.g., in $\mu g/m^3$). The latter values as well as RfCs are regulating and restricting air pollutant concentrations in the environment (Benson *et al.* 2002; Health Canada 1996). These inhalation rates are also used to estimate intakes and uptakes (*e.g.*, in $\mu g/m^3$ and/or μg/kg-day) by individuals exposed to airborne chemical concentrations (Paustenbach 2001). Oxygen intake from daily air inhalation is consumed to fill physiological needs that vary according to the total daily energy requirements (TDERs) of the individual (IDECG 1990; Layton 1993; Lucas 1989). The main component of the TDER, the basal metabolic rate (BMR), is nearly proportional to body weight. Moreover, increments in energy expenditures brought about by most physical activities where body weight is supported against gravity (e.g., walking, but not cycling on a stationary cycle ergometer) are also directly proportional to body weight and constitute another portion of the TDER (IDECG 1990; IOM 2002; Lucas 1989). However, there has been no study to evaluate daily inhalation rates according to body weight for a single cohort of individuals. Daily inhalation estimates for a given population of individuals are simply associated with bodyweights from another population of the same age group (Finley *et al.* 1994; Layton 1993; Richardson 1997). Using such practices, underweight values overestimate daily inhalation rates whereas overweight values underestimate them, when daily inhalation estimates are expressed per unit of body weight (Torun *et al.* 1996). Therefore, it is essential to obtain daily inhalation estimates per unit of body weight that are close to biological reality in order to estimate daily intakes and uptakes resulting from air pollutant exposure and thus reach proper decision for regulatory purposes. Errors are also introduced in establishing criteria and guideline values when the distribution of breathing rates is considered independent of the distribution of body weights.

The doubly labeled water (DLW) method provides accurate and precise TDEE measurements for unrestrained free-living males and females from birth to old age during real-life situations in their normal surroundings (Butte 2000; IDECG 1990; IOM 2002; Lucas 1989). It also provides the most accurate measure of the energy cost for growth (ECG) for young individuals during the first years of life up to pubertal ages (Butte *et al.* 1990; Butte 2000; Butte *et al.* 2000). The DLW method measures the turnover of hydrogen and oxygen into water as well as the carbon dioxide rate production by monitoring the differential disappearance of the stable isotopes deuterium (^{2}H) and heavy oxygen-18 (^{18}O) in urine, saliva, or blood samples by gas-isotope-ratio mass spectrometry of free-living people over a long period of time—from 7 to 21 days, after subjects have been given an oral loading dose of doubly labeled water: ^2H_2O and $H_2^{18}O$ (Butte 2000; Butte *et al.* 1990; IDECG 1990; IOM 2002; Lucas 1989; Torun *et al.* 1996). This method provides the most exact quantitative TDEE and ECG measurements for males and females. Those measurements can be converted into physiological daily inhalation rates using the equation developed by Layton (1993). The resulting inhalation rates can easily be expressed per unit of body weight because the DLW method requires systematic weight and body mass index

(BMI) measurements of all subjects. BMRs are also measured by indirect calorimetry (Butte 2000; IDECG 1990; IOM 2002; Lucas 1989). The present article is intended to determine physiological daily inhalation rates as a function of age for individuals aged 1 month to 96 years old based on DLW measurements. The first objective is to establish adequate daily inhalation rates for air quality and standard calculations for non-carcinogenic compounds. The second objective is to obtain distribution percentile values for males and females who inhale the highest volumes of air per kg of bodyweight (thus predisposed to larger intake of air pollutants by the respiratory tract) for use in health risk assessment.

RELEVANT METHODOLOGICAL APPROACHES

Study Design and Subjects

The present study was designed to calculate physiological daily inhalation rates (expressed in m^3/day and m^3/kg-day) for a wide range of individuals taken from different age groups and physiological conditions: healthy newborns aged 3 to 5 weeks old ($n = 33$), healthy normal-weight males and females aged 2.6 months to 96 years ($n = 1252$), low-BMI subjects (underweight women, $n = 17$; adults from less affluent societies, $n = 59$) and overweight/obese individuals ($n = 679$) as well as athletes, explorers, and soldiers when reaching very high energy expenditures ($n = 170$). Data for underweight, healthy normal-weight, and overweight/obese individuals were gathered and defined according to BMI cut-offs. Data for newborns were included regardless of BMI values, because they have been clinically evaluated as being healthy infants. Underweight adults are defined as those having BMIs lower than 18.5 kg/m^2. Healthy normal-weight individuals are defined as those having BMIs between the 3rd and 97th percentiles for infants and toddlers under 3 years old, corresponding to the 85th percentile or below for children and teenagers aged 3 to 19 years, and varying between 18.5 and 24.5 kg/m^2 for adults over 19 up to 96 years. Of course, overweight individuals are defined as those having BMIs higher than the 97th percentiles for infants and toddlers under 3 years old and higher than the 85th percentile for individuals aged 3 to 19 years. Overweight adults over 19 years of age have BMIs varying from 25 to 30 kg/m^2, whereas obese individuals have BMIs greater than 30 kg/m^2 (Kuczmarski *et al.* 2000; NHLBI/NIDDK 1998; Toriano *et al.* 1995; WHO 1998).

The aggregate data for normal-weight and overweight/obese males ($n = 746$) and females ($n = 1185$) were grouped in smaller age groups of 30 subjects. Means and standard deviations of body weights, BMIs, basal energy expenditures (BEEs), TDERs and daily metabolic equivalent values (DMET) or TDER/BEE ratios have been calculated for all sub-groups as well as for newborns. BEEs correspond to BMRs expressed on a 24-hour basis, whereas DMETs (daily BEE multiplier) represent physical activity levels or PAL when adding the ECG. Physiological daily inhalation rates have been calculated for each age group. For each set of data concerning overweight/obese age groups, additional set of values have been calculated based on normal-weight parameters for comparison purposes. Mean age statistical differences between each age group of normal-weight and overweight/obese individuals have been calculated by using Mann-Whitney tests. The 1st and 99th percentiles of the age for underweight sub-groups and athletes, explorer, and soldiers have been derived from the standard deviations associated with their mean ages in order to estimate the ECG values. Distributions of the physiological daily inhalation rates and the associated statistical p values bases on the Shapiro-Wilk normality tests have been calculated for each normal-weight and overweight/obese sub-group.

Data Selection

Published mean measured data for formula-fed very low-birth-weight infants aged 3 weeks in Reichman *et al.* (1981, 1982) and breastfed and formula-fed infants aged 1 month in Butte *et al.* (1990) as well as data reported in Black *et al.* (1996) for underweight women with anorexia nervosa, adults from less affluent societies (low-BMI subjects), athletes, explorers, and soldiers have been used in the present article ($n = 279$). A database reported in the IOM (2002) has been preferentially used to characterize normal-weight and overweight/obese groups because individual data including BMI, body weight, BMR, and TDEE measurements were available for each of the 1,931 subjects aged 2.6 months to 96 years. Such sets of measured values per subject, which were essentials for adequate data calculations per age and BMI sub-groups, were not available in other studies as in Black *et al.* (1996), Coward (1998) and Torun *et al.* (1996). TDEEs over a 6-hour period for infants aged 3 weeks, sleeping metabolic rates and minimal observable energy expenditures for 1-month old infants as well as BEEs for males and females aged 2.6 months to 96 years were measured by indirect calorimetry (Black *et al.* 1996; Butte *et al.* 1990; Reichman *et al.* 1981, 1982; IOM 2002). The nutritional balance for infants aged 3 weeks was determined by measurements of intakes (formula) and outputs (urine and stool) over three days (Reichman *et al.* 1981, 1982). TDEE measurements from the DLW method were based on the monitoring of stable isotopic forms of water (^2H_2O and $H_2^{18}O$) in urine samples from unrestrained free-living males and females during real-life situations in their normal surroundings. Deuterium (^2H) and heavy oxygen-18 (^{18}O) were measured by gas-isotope-ratio mass spectrometry during 14-day periods in Butte *et al.* (1990) and for a duration varying between 7 to 21 days in other studies reported in Black *et al.* (1996) and IOM (2002), thus totalizing an aggregate period of over 30,000 days.

Doubly Labeled Water Method

The first field applications of the DLW method in human subjects based on the work of Lifson *et al.* (1955) were reported in Schoeller and van Santen (1982) and Prentice *et al.* (1985). This was made possible due to the increased sensitivity and accuracy of isotope measurements by gas-isotope-ratio mass spectrometers (IDECG 1990). Rapid expansion of the literature using the DLW method has been observed since then with a tremendous number of studies on TDEEs for small cohorts of free-living males and females. The disappearance rate of deuterium (^2H) with the DLW method reflects water output and that of heavy oxygen-18 (^{18}O) represents water output plus carbon dioxide (CO_2) production rates, because of the rapid equilibration of the body water and bicarbonate pools by carbonic anhydrase. Differences between the two disappearance rates are therefore used to calculate the CO_2 production rate. The energy released per liter of CO_2 varies with the average respiratory quotient and hence with the substrate mixture oxidized by the body. TDEEs are determined from CO_2 production rates using classic respirometry formulas in which values for the respiratory quotient ($RQ = CO_{2produced}/O_{2consumed}$) are derived from the composition of the diet during the period of time of each study. The ratio of the CO_2 produced versus the O_2 consumed by the biological oxidation of a representative sample of the diet (RQ) can also be measured directly by respiratory gas exchange measurements. Nevertheless, the respiratory quotient has a relatively small effect on DLW measurements of TDEEs. The precision of DLW measurements, as assessed by the variability of the individual's DLW measurements from indirect calorimetry assessments, varies between 2 to 5% in different validation studies (IDECG 1990; Torun *et al.* 1996).

Physiological Daily Inhalation Calculations

TDEE measurements encompass all daily energy expenditures of free-living people, except for the ECG, which is determined in the present article from DLW measurements (Butte 2000; Butte *et al.* 1990, 2000; IDECG 1990; Lucas 1989). Summation of the TDEE and ECG constitutes the TDER value, which in turn is converted in the present paper into physiological daily inhalation rates, using the Layton equation:

$$\mathrm{PDIR} = (\mathrm{TDEE} + \mathrm{ECG}) * \mathrm{H} * \mathrm{VQ}\ 10^{-3} \tag{1}$$

where,
PDIR = physiological daily inhalation rate (m^3/day)
TDEE = total daily energy expenditure (kcal/day)
ECG = stored daily energy cost for growth (kcal/day)
H = oxygen uptake factor, volume of 0.21 L of oxygen (at standard temperature and pressure, dry air) consumed to produce 1 kcal of energy expended
VQ = ventilatory equivalent ratio of the minute volume (V_E at body temperature pressure saturation) to the oxygen uptake rate (VO_2 at standard temperature and pressure, dry air) $V_E/VO_2 = 27$ (unitless)
10^{-3} = conversion factor (L/m^3)

Metabolic oxidation of each gram of carbohydrate, protein, and fat requires the metabolic consumption of 0.83, 0.97, and 2 liters of oxygen (O_2), respectively and yields energy production rates of 5.0, 4.5, and 4.7 kcal/L of O_2, respectively (Layton 1993). An H value of 0.21 L O_2 kcal^{-1} has been calculated by Layton (1993), based on the mean nutriment intake contributions of an American population (16% of protein, 39.8% of fat, and 43.6% of carbohydrate). Using Canadian mean nutriment intake contributions observed and compiled by Brault-Dubuc and Mongeau (1989) during a 10-year span (14.2% of protein, 37.7% of fat, 48.6% of carbohydrate), a comparable weighted average breakdown of an H value was calculated. Thus, the H value of 0.21 L O_2 kcal^{-1} was used in the present article.

Energy Cost for Growth

The ECG must be added to the TDEE to obtain the TDER values (Butte 2000; Lucas 1989). The ECG varies during childhood, particularly during the childhood adiposity rebound and adolescent growth spurt. ECG values as a function of age have been calculated from DLW measurements in regard to 933 infants, children, and adolescents by Butte (2000) and Butte *et al.* (1990, 2000), in consistency with Tanner's weight velocities and the energy content of 20 kJ/g tissue deposits (Tanner *et al.* 1996).

Growth in the first two years of life

Growth during the first two years of life is characterized by a gradual deceleration in both linear growth velocity and weight gain rates, both of which level off at 2 to 3 years of age (Rogol *et al.* 2000). During this period, infants exhibit the pattern of growth that is consistent with their genetic backgrounds. Physiological measurements performed in 13 infants aged 3 weeks demonstrated that the ECG corresponds to a mean increase of 108% of the TDEE (Reichman *et al.* 1981, 1982). The ECG for 10 breastfed infants aged 1 month (+45% of the TDEE) based on DLW measurements has been shown by Butte *et al.* (1990) to be lower than the ECG for 10 formula-fed infants of the same age (+63% of the TDEE). ECGs for breastfed and formula-fed girls and boys aged 1 month or less require mean increases of 43.6 and 46.3% of the TDEE, respectively (Table Web-1; Butte 2000). Increases of 58 and 63% of the TDEE are required for ECGs for girls and boys, respectively, aged between 1 and 2 months. The ECG then drops dramatically with age and reaches lowest values of 1.5 and 1.7% of the TDEE at 2 years of age for boys and girls, respectively (Butte *et al.* 1990, $n = 40$; Butte 2000, $n = 338$; Butte *et al.* 2000, $n = 67$).

Prepubertal growth

Prepubertal growth is a relatively stable process. Infancy shifts in the growth pattern are complete and the child follows the trajectory attained previously. The lowest values for growth velocity reached at the age of 2 years maintain the same level between 3 to less than 5 years of age (+1.5% of the TDEE for boys; +1.7% of the TDEE for girls; $n = 192$ for both genders). The ECG remains low until the pubertal growth spurt with a TDEE increase similar to the increase in children aged 1 year (Butte 2000; Butte *et al.* 2000; IOM 2002; $n = 556$). The ECG for girls aged 5 to less than 11 years corresponds to a TDEE increase of 2.5%, compared to 3.0% for boys aged 5 to less than 13 years.

Pubertal growth

Puberty is a dynamic period of development marked by rapid changes in body size, shape, and composition, all of which are sexually dimorphic (Rogol *et al.* 2000). Puberty in girls begins approximately at the age of 9 or 10 years and usually culminates with the onset of menstruation between ages of 11 and 16 years, whereas puberty in boys begins at 13 years (Guyton 1991). The onset of puberty also corresponds to a skeletal (biological) age of approximately 11 years for girls and 13 for boys (Rogol *et al.* 2000; Tanner *et al.* 1975). Complete process of pubertal growth spurts for teenagers and young adults is carried out between 11 and 18 years old for females and between 13 and 20 years for males, but may also continue for the latter until 25 years of age: deposition of bone minerals, fat free and fat mass accumulations, increases in skeletal size and in muscle mass, gain in stature, lean body mass and body weight, and epiphyseal fusion (Forbes 1987; Rogol *et al.* 2000; IOM 2002). Based on DLW measurements ($n = 93$), the ECG for teenagers and young adults requires an increase of 4.2% of the TDEE in females aged 11 to 18 years and males aged 13 to 20 years (Table Web-1; Butte 2000; Forbes 1987; IOM 2002). The ECG for males decreases between 4.2 to 0.0% according to age from 20 up to 25 years (Table Web-1; Butte 2000; Forbes 1987; IOM 2002). Thus, proportional decrease values of ECG for males are considered in the present article, namely calculated as being 3.3, 2.5, 1.7, and 0.8% of the TDEE for males aged 21, 22, 23, and 24 years, respectively (Table Web-1).

RESULTS AND STATISTICAL ANALYSIS

Twelve tables and two figures are available on the Québec Ministry of Sustainable Development, Environment and Parks website (MDDEP 2006) and may be consulted in English at http://www.mddep.gouv.qc.ca/air/inhalation/index_en.htm, or in French at http://www.mddep.gouv.qc.ca/air/inhalation/index.htm. Further information can also be obtained by contacting the lead author by e-mail.

ECGs for males and females from birth up to 25 years of age (in % of TDEE) are given in Table Web-1. Means of measured body weights (in kg) with standard deviation (S.D.) values are reported in Tables Web-2, Web-3, Web-5, Web-7, and Web-10 to Web-12, and in Tables 1–7. BMI measurements (means in kg/m^2 ± S.D.) are

Table 1. Physiological daily inhalation rates for newborns aged 1 month or less.

Age group (days)	n	Body weight (kg) Mean ± S.D.	Physiological daily inhalation rate[e] Mean ± S.D. (m^3/day)	(m^3/kg-day)	DMET[h] (unitless) Mean ± S.D.
21 (3 weeks)	13[a,c]	1.2 ± 0.2	0.85 ± 0.17[f]	0.739 ± 0.093[f]	2.77 ± 0.41
32 (~1 month)	10[b,d]	4.7 ± 0.7	2.45 ± 0.59[g]	0.527 ± 0.096[g]	1.89 ± 0.38
33 (~1 month)	10[a,d]	4.8 ± 0.3	2.99 ± 0.47[g]	0.618 ± 0.090[g]	2.11 ± 0.36

[a]Formula-fed infants.
[b]Breast-fed infants.
[c]Healthy infants with very low birth weight (Reichman *et al.* 1981, 1982).
[d]Infants evaluated as being clinically healthy and neither underweight nor overweight (Butte *et al.* 1990).
[e]Total daily energy requirements (TDERs) reported in Table Web-2 were converted into physiological daily inhalation rates by the following equation: TDER*H*(V_E/VO_2)*10^{-3}. H = 0.21 L of O_2/Kcal and V_E/VO_2 = 27 (Layton 1993). TDER = total daily energy requirement. TDER = (TDEE + ECG). TDEE = total daily energy expenditure. ECG = stored daily energy cost for growth. ECGs from Table Web-1 were initially added to the basic TDEEs in order to obtain the appropriate TDERs (Table Web-2).
[f]TDEEs based on nutritional balance measurements (intake and output analysis) during 3-day periods for each infant.
[g]TDEEs based on ^2H_2O and $H_2^{18}O$ disappearance rates from urine monitored by gaz-isotope-ratio mass spectrometry during 14-day periods.
[h]Daily metabolic equivalent or daily BEE multiplier (TDER/BEE). BEEs or basal energy expenditures (BMRs expressed on a 24-hour basis) were measured by indirect calorimetry (Butte *et al.* 1990; Reichman *et al.* 1981, 1982).
Tables Web-1 and Web-2 are available on the Québec Ministry of Sustainable Development, Environment and Parks website (MDDEP 2006). n = number of individuals; S.D. = standard deviation.

Table 2. Distribution percentiles of physiological daily inhalation rates (m^3/day) for free-living normal-weight males and females aged 2.6 months to 96 years.

Gender and age group (years)	n	Body weight[a] (kg) Mean ± S.D.	Observed p value[b]	Physiological daily inhalation rates[c] (m^3/day) Mean ± S.D.	Percentile[d] 2.5nd	5th	10th	25th	50th	75th	90th	95th	97.5th	99th
Males														
0.22 to <0.5	32	6.7 ± 1.0	0.032	3.38 ± 0.72	1.97	2.19	2.46	2.89	3.38	3.87	4.30	4.57	4.79	5.06
0.5 to <1	40	8.8 ± 1.1	0.700	4.22 ± 0.79	2.68	2.92	3.21	3.69	4.22	4.75	5.23	5.51	5.76	6.05
1 to <2	35	10.6 ± 1.1	0.898	5.12 ± 0.88	3.40	3.68	3.99	4.53	5.12	5.71	6.25	6.56	6.84	7.16
2 to <5	25	15.3 ± 3.4	0.101	7.60 ± 1.28	5.08	5.49	5.95	6.73	7.60	8.47	9.25	9.71	10.12	10.59
5 to <7	96	19.8 ± 2.1	0.176	8.64 ± 1.23	6.23	6.61	7.06	7.81	8.64	9.47	10.21	10.66	11.05	11.50
7 to <11	38	28.9 ± 5.6	0.326	10.59 ± 1.99	6.69	7.32	8.04	9.25	10.59	11.94	13.14	13.87	14.49	15.22
11 to <23	30	58.6 ± 13.9	0.851	17.23 ± 3.67	10.04	11.19	12.53	14.75	17.23	19.70	21.93	23.26	24.41	25.76
23 to <30	34	70.9 ± 6.5	0.238	17.48 ± 2.81	11.97	12.86	13.88	15.59	17.48	19.38	21.08	22.11	22.99	24.02
30 to <40	41	71.5 ± 6.8	0.087	16.88 ± 2.50	11.98	12.77	13.68	15.20	16.88	18.57	20.09	21.00	21.79	22.70
40 to <65	33	71.1 ± 7.2	0.275	16.24 ± 2.67	11.00	11.84	12.81	14.44	16.24	18.04	19.67	20.64	21.48	22.46
65 to ≤96	50	68.9 ± 6.7	0.293	12.96 ± 2.48	8.11	8.89	9.79	11.29	12.96	14.63	16.13	17.03	17.81	18.72
Females														
0.22 to <0.5	53	6.5 ± 0.9	0.002	3.26 ± 0.66	1.96	2.17	2.41	2.81	3.26	3.71	4.11	4.36	4.56	4.81
0.5 to <1	63	8.5 ± 1.0	0.699	3.96 ± 0.72	2.56	2.78	3.05	3.48	3.96	4.45	4.88	5.14	5.37	5.63
1 to <2	66	10.6 ± 1.3	0.044	4.78 ± 0.96	2.90	3.20	3.55	4.13	4.78	5.43	6.01	6.36	6.67	7.02
2 to <5	36	14.4 ± 3.0	0.114	7.06 ± 1.16	4.79	5.15	5.57	6.28	7.06	7.84	8.54	8.97	9.33	9.76
5 to <7	102	19.7 ± 2.3	0.699	8.22 ± 1.31	5.65	6.06	6.54	7.34	8.22	9.11	9.90	10.38	10.79	11.27
7 to <11	161	28.3 ± 4.4	0.0001	9.84 ± 1.69	6.53	7.07	7.68	8.70	9.84	10.98	12.00	12.61	13.15	13.76
11 to <23	87	50.0 ± 8.9	0.895	13.28 ± 2.60	8.18	9.00	9.94	11.52	13.28	15.03	16.61	17.56	18.38	19.33
23 to <30	68	59.2 ± 6.6	0.266	13.67 ± 2.28	9.20	9.91	10.74	12.13	13.67	15.21	16.59	17.42	18.14	18.98
30 to <40	59	58.7 ± 5.9	0.113	13.68 ± 1.76	10.22	10.78	11.42	12.49	13.68	14.87	15.94	16.58	17.13	17.78
40 to <65	58	58.8 ± 5.1	0.561	12.31 ± 2.07	8.26	8.91	9.66	10.92	12.31	13.70	14.96	15.71	16.36	17.12
65 to ≤96	45	57.2 ± 7.3	0.266	9.80 ± 2.17	5.55	6.24	7.02	8.34	9.80	11.27	12.58	13.37	14.06	14.85

[a]Measured body weight. Normal-weight individuals defined according to the body mass index (BMI) cut-offs. BMIs for sub-groups are reported in Table Web-4.
[b]Observed p values based on Shapiro-Wilk normality tests. Daily metabolic equivalent values are given in Table 8.
[c]Total daily energy requirements (TDERs) reported in Table Web-4 (in kcal/day) were converted into physiological daily inhalation rates by the following equation: $TDER^{*}H^{*}(V_E/VO_2)^{*}10^{-3}$. H = 0.21 L of O_2/Kcal and $V_E/VO_2 = 27$ (Layton 1993). TDER = (TDEE + ECG). TDEE = total daily energy expenditure. ECG = stored daily energy cost for growth.
TDEEs in Table Web-3 were based on ^2H_2O and $H_2^{18}O$ disappearance rates from urine monitored by gaz-isotope-ratio mass spectrometry during 7- to 21-day periods for 1,252 individuals aged 2.6 months to 96 years (IOM 2002). ECGs from Table Web-1 were initially added to the basic TDEEs in order to obtain the appropriate TDERs.
[d]Percentiles based on a normal distribution assumption for all age groups.
n = number of individuals; S.D.= standard deviation.
Tables Web-1, Web-3, and Web-4 are available on the Québec Ministry of Sustainable Development, Environment and Parks website (MDDEP 2006).

Table 3. Distribution percentiles of physiological daily inhalation rates (m^3/day) for free-living normal-weight and overweight/obese males aged 4 to 96 years.

Male age group (years)	n	Body weight[a] (kg) Mean ± S.D.	Observed p value[b]	Physiological daily inhalation rates[c] (m^3/day) Mean ± S.D.	Percentile[d] 2.5nd	5th	10th	25th	50th	75th	90th	95th	97.5th	99th
Normal-weight														
4 to <5.1	77	19.0 ± 1.9	0.387	7.90 ± 0.97	6.00	6.31	6.66	7.25	7.90	8.56	9.15	9.50	9.81	10.16
5.1 to <9.1	52	22.6 ± 3.5	0.157	9.14 ± 1.44	6.31	6.77	7.29	8.17	9.14	10.11	10.99	11.51	11.97	12.49
9.1 to <18.1	36	41.4 ± 12.1	0.307	13.69 ± 3.95	5.95	7.19	8.63	11.02	13.69	16.35	18.75	20.19	21.43	22.88
18.1 to <40.1	98	71.3 ± 6.1	0.234	17.41 ± 2.70	12.11	12.96	13.94	15.58	17.41	19.23	20.87	21.85	22.70	23.69
40.1 to <70.1	34	70.0 ± 7.8	0.374	15.60 ± 2.89	9.94	10.85	11.89	13.65	15.60	17.54	19.30	20.34	21.25	22.31
70.1 to ≤96	38	68.9 ± 6.8	0.655	12.69 ± 2.33	8.11	8.85	9.70	11.11	12.69	14.26	15.68	16.53	17.26	18.12
Overweight/obese														
4 to <5.1	54	26.5 ± 4.9	0.454	9.59 ± 1.26	7.13	7.52	7.98	8.74	9.59	10.44	11.21	11.66	12.06	12.52
5.1 to <9.1	40	32.5 ± 9.2	0.135	10.88 ± 2.49	6.00	6.78	7.69	9.20	10.88	12.56	14.07	14.98	15.77	16.68
9.1 to <18.1	33	55.8 ± 10.8	0.454	14.52 ± 1.98	10.63	11.25	11.98	13.18	14.52	15.85	17.06	17.78	18.40	19.13
18.1 to <40.1	52	98.1 ± 25.2	0.245	20.39 ± 3.62	13.30	14.44	15.75	17.95	20.39	22.83	25.03	26.35	27.49	28.81
40.1 to <70.1	81	93.2 ± 14.9	0.003	17.96 ± 3.71	10.68	11.85	13.20	15.45	17.96	20.46	22.71	24.06	25.23	26.59
70.1 to ≤96	32	82.3 ± 10.3	0.025	14.23 ± 2.94	8.47	9.40	10.46	12.25	14.23	16.21	18.00	19.06	19.99	21.07

[a]Measured body weight. Normal-weight and overweight/obese males defined according to the body mass index (BMI) cut-offs. BMIs for sub-groups are reported in Table Web-6.
[b]Observed p values based on Shapiro-Wilk normality tests. Daily metabolic equivalent values are given in Table 9.
[c]Total daily energy requirements (TDERs) reported in Table Web-6 (in kcal/day) were converted into physiological daily inhalation rates by the following equation: $TDER^{*}H^{*}(V_E/VO_2)^{*}10^{-3}$. H = 0.21 L of O_2/Kcal and $V_E/VO_2 = 27$ (Layton 1993). TDER = (TDEE + ECG). TDEE = total daily energy expenditure (Table Web-5).
ECG = stored daily energy cost for growth (Table Web-6). TDEEs were based on ^2H_2O and $H_2^{18}O$ disappearance rates from urine monitored by gaz-isotope-ratio mass spectrometry during 7- to 21-day periods for 627 males aged 4 to 96 years (IOM 2002). ECGs from Table Web-1 were initially added to the basic TDEEs in order to obtain the TDER values.
[d]Percentiles based on a normal distribution assumption for all age groups. n = number of individuals; S.D. = standard deviation.
Tables Web-1, Web-5, and Web-6 are available on the Québec Ministry of Sustainable Development, Environment and Parks website (MDDEP 2006).

Table 4. Distribution percentiles of physiological daily inhalation rates (m^3/day) for free-living normal-weight and overweight/obese females aged 4 to 96 years.

Female age group (years)	n	Body weight[a] (kg) Mean ± S.D.	Observed p value[b]	Physiological daily inhalation rates[c] (m^3/day) Mean ± S.D.	Percentile[d] 2.5nd	5th	10th	25th	50th	75th	90th	95th	97.5th	99th
Normal-weight														
4 to <5.1	82	18.7 ± 2.0	0.433	7.41 ± 0.91	5.63	5.92	6.25	6.80	7.41	8.02	8.57	8.90	9.19	9.52
5.1 to <9.1	151	25.5 ± 4.1	0.036	9.39 ± 1.62	6.21	6.72	7.31	8.30	9.39	10.48	11.47	12.05	12.56	13.16
9.1 to <18.1	124	42.7 ± 11.1	0.005	12.04 ± 2.86	6.44	7.34	8.38	10.11	12.04	13.97	15.70	16.74	17.64	18.68
18.1 to <40.1	135	59.1 ± 6.3	0.092	13.73 ± 2.01	9.78	10.41	11.15	12.37	13.73	15.09	16.31	17.04	17.68	18.41
40.1 to <70.1	79	59.1 ± 5.3	0.450	11.93 ± 2.16	7.70	8.38	9.16	10.47	11.93	13.38	14.69	15.48	16.16	16.95
70.1 to ≤96	24	54.8 ± 7.5	0.430	8.87 ± 1.79	5.36	5.92	6.57	7.66	8.87	10.07	11.16	11.81	12.38	13.03
Overweight/obese														
4 to <5.1	56	26.1 ± 5.5	0.771	8.70 ± 1.13	6.49	6.84	7.26	7.94	8.70	9.47	10.15	10.56	10.92	11.33
5.1 to <9.1	68	34.6 ± 9.9	0.144	10.55 ± 2.23	6.18	6.88	7.69	9.05	10.55	12.06	13.41	14.22	14.93	15.75
9.1 to <18.1	68	59.2 ± 12.8	0.580	14.27 ± 2.70	8.98	9.83	10.81	12.45	14.27	16.09	17.73	18.71	19.56	20.55
18.1 to <40.1	76	84.4 ± 16.3	0.285	15.66 ± 2.11	11.52	12.18	12.95	14.23	15.66	17.08	18.36	19.13	19.80	20.57
40.1 to <70.1	91	81.7 ± 17.2	0.0001	13.01 ± 2.82	7.49	8.37	9.40	11.11	13.01	14.91	16.62	17.64	18.53	19.56
70.1 to ≤96	28	69.0 ± 7.8	0.443	10.00 ± 1.78	6.51	7.07	7.71	8.80	10.00	11.20	12.28	12.93	13.49	14.14

[a]Measured body weight. Normal-weight and overweight/obese females defined according to the body mass index (BMI) cut-offs. BMIs for sub-groups are reported in Table Web-8.
[b]Observed p values based on Shapiro-Wilk normality tests. Daily metabolic equivalent values are given in Table 10.
[c]Total daily energy requirements (TDERs) reported in Table Web-8 (in kcal/day) were converted into physiological daily inhalation rates by the following equation: $TDER^{*}H^{*}(V_E/VO_2)^{*}10^{-3}$. H = 0.21 L of O_2/Kcal and $V_E/VO_2 = 27$ (Layton 1993). TDER = (TDEE + ECG). TDEE = total daily energy expenditure (Table Web-7).
ECG = stored daily energy cost for growth (Table Web-8). TDEEs were based on ^2H_2O and $H_2^{18}O$ disappearance rates from urine monitored by gaz-isotope-ratio mass spectrometry during 7- to 21-day periods for 982 females aged 4 to 96 years (IOM 2002). ECGs from Table Web-1 were initially added to the basic TDEEs in order to obtain the TDER values.
[d]Percentiles based on a normal distribution assumption for all age groups. n = number of individuals; S.D.=standard deviation.
Tables Web-1, Web-7, and Web-8 are available on the Québec Ministry of Sustainable Development, Environment and Parks website (MDDEP 2006).

Table 5. Physiological daily inhalation rates for free-living adults from less affluent societies.

Subjects	n	Age (years) Mean ± S.D.	Body weight[e] (kg) Mean ± S.D.	Physiological daily inhalation rate[f] (m^3/day)	(m^3/kg-day)	DMET[g] (unitless)
Males						
Sub-group A[a]	6	26.8 ± 4.4	55.0 ± 4.0	15.6	0.283	1.8
Sub-group B[a]	5	25.8 ± 4.1	58.4 ± 2.6	15.6	0.266	1.7
Sub-group C[b]	16	35.0 ± 1.0	61.6 ± 6.4	25.5	0.414	3.0
Females						
Sub-group D[c]	15	35.7 ± 6.8	54.1 ± 12.4	11.7	0.217	1.6
Sub-group E[d]	10	30.0 ± 2.6	49.4 ± 5.3	13.6	0.276	2.0
Sub-group F[d]	7	26.0 ± 3.4	50.2 ± 6.0	13.1	0.260	1.7

[a]Thin Chilean laborers. [b]Gambian laborers. [c]Guatemalan mothers. [d]Gambian farmers.
[e]Measured body weight. [f]Total daily energy requirements (TDERs) were converted into physiological daily inhalation rates by the following equation: TDER*H* $(V_E/VO_2)*10^{-3}$. H $= 0.21$ L of O_2/Kcal and $V_E/VO_2 = 27$ (Layton 1993). TDER = (TDEE + ECG).
TDEE = total daily energy expenditure. ECG = stored daily energy cost for growth. TDEEs were based on ^2H_2O and $H_2^{18}O$ disappearance rates from urine monitored by gaz-isotope-ratio mass spectrometry during 7- to 21-day periods (Black *et al.* 1996).
[g]Daily metabolic equivalent or daily BEE multiplier (TDER/BEE). BEEs or basal energy expenditures (BMRs expressed on a 24-hour basis) were measured by indirect calorimetry (Black *et al.* 1996).
Body mass index values, BEEs, TDEEs, ECGs, and TDERs are reported in Table Web-10, which is available on the Québec Ministry of Sustainable Development, Environment and Parks website (MDDEP 2006).
n = number of individuals; S.D. = standard deviation.

presented in Tables Web-4, Web-6, Web-8, and Web-10 to Web-12. BEEs measured by indirect calorimetry and TDEEs from DLW measurements (means in kcal/day and kcal/kg-day ± S.D.) are reported in Tables Web-2, Web-3, Web-5, Web-7, and Web-10 to Web 12. ECGs and TDERs (means in kcal/day and kcal/kg-day ± S.D.) for newborns, normal-weight, overweight/obese, and underweight individuals as well as adults from less affluent societies are summarized in Tables Web-2, Web-4, Web-6, Web-8, Web-10, and Web-11. Similar mean data for athletes, explorers, and soldiers are presented in Table Web-12. Mean physiological daily inhalation rates for newborns (in m^3/day and m^3/kg-day ± S.D.) are presented in Table 1. Those data are consistent with values related to older infants (Tables 2–4, 8–10). No distribution is however given for newborns because the normality hypothesis could not be tested due to the insufficient number of observations for each sub-population (10 to 13). Distribution of physiological daily inhalation rates and observed p values for normal-weight and overweight/obese sub-groups of individuals are given in Tables 2–4 for percentile values expressed in m^3/day, and in Tables 8–10 for values expressed in m^3/kg-day. In Tables 5–7, mean physiological daily inhalation rates (in m^3/day and m^3/kg-day ± S.D.) for underweight women, adults from less affluent

Table 6. Physiological daily inhalation rates for underweight free-living adult females with anorexia nervosa and for control sub-groups.

Female sub-groups[a]	n	Age (years) Mean ± S.D.	Body weight[e] (kg) Mean ± S.D.	Physiological daily inhalation rate[f] (m^3/day)	(m^3/kg-day)	DMET[g] (unitless)
Women with anorexia nervosa						
Sub-group A	8	27.8 ± 5.2	43.0 ± 5.6	16.4	0.382	2.6
Sub-group B	6	24.5 ± 6.9	42.5 ± 9.4	11.2	0.263	2.0
Sub-group C	3	36.0 ± 10.8	40.6 ± 1.0	9.9	0.244	1.5
Control sub-groups						
Sub-group A	11	24.5 ± 4.2	57.5 ± 5.1	13.3	0.232	1.8
Sub-group B	6	24.8 ± 7.0	42.5 ± 9.4	11.2	0.264	1.5

[a]Measured body weight.
[b]Total daily energy requirements (TDERs) were converted into physiological daily inhalation rates by the following equation: TDER*H*$(V_E/VO_2)*10^{-3}$. H = 0.21 L of O_2/Kcal and $V_E/VO_2 = 27$ (Layton 1993). TDER = (TDEE + ECG).
TDEE = total daily energy expenditure. ECG = stored daily energy cost for growth. TDEEs were based on^2H_2O and $H_2^{18}O$ disappearance rates from urine monitored by gaz-isotope-ratio mass spectrometry during 7- to 21-day periods (Black *et al.* 1996).
[c]Daily metabolic equivalent or daily BEE multiplier (TDER/BEE). BEEs or basal energy expenditures (BMRs expressed on a 24-hour basis) were measured by indirect calorimetry (Black *et al.* 1996).
Body mass index values, BEEs, TDEEs, ECGs, and TDERs are reported in Table Web-11, which is available on the Québec Ministry of Sustainable Development, Environment and Parks website (MDDEP 2006).
n = number of individuals; S.D. = standard deviation.

societies, athletes, explorers, and soldiers are also given. DMET values (±S.D.) are reported for each sub-group of individuals in Tables 1 and 5–10.

Results of Mann-Whitney statistical tests are presented in Table Web-9. Mean ages of 7 out of 12 sets of normal-weight and overweight/obese sub-groups are statistically different ($p < 0.05$). However, such differences are small compared the wide span of age in most age groups. For instance, mean ages between each sub-group of females aged more than 5 to 9 years are different by 3 months, whereas those for sub-groups aged more than 9 to 18 years old are different by 1.5 years (Table Web-9). Moreover, physiological daily inhalation rates expressed in m^3/kg-day for most sub-populations in normal-weight and overweight/obese groups determined for individuals aged 2.6 months to 96 years (Tables 8–10) are consistent with normality distributions based on Shapiro-Wilk normality tests ($p \geq 0.05$). Percentile physiological daily inhalation rates for the few other sub-populations in normal-weight groups ($p < 0.05$), calculated under the normality hypothesis, have been considered as being conservative for use in air quality criteria and guideline calculations. Moreover, physiological daily inhalation values for 91% of sub-populations in normal-weight groups are equal to or higher than a p value of 0.01 (Table 8). Positive skewness values and kurtosis values higher than 3 have been calculated in all cases, except for

Table 7. Physiological daily inhalation rates for free-living athletes, explorers and soldiers during extreme physical activity.

Subjects	n	Age (years) Mean ± S.D.	Body weight[d] (kg) Mean ± S.D.	Physiological daily inhalation rate[e] (m^3/day)	(m^3/kg-day)	DMET[f] (unitless)
Male athletes						
Swimmers	5	19.8 ± 1.6	80.3 ± 7.2	23.2	0.289	2.2
Cyclists[a]	4	24 ± n.d.	68.4 ± n.d.	45.9	0.672	4.7
Cross-country skiers	4	26 ± 1.8	75.1 ± 4.9	41.2	0.549	3.5
Mountaineers[b]	3	35.3 ± 4.0	64.3 ± 8.6	19.8	0.309	2.4
Female athletes						
Swimmers	3	20.7 ± 1.5	67.8 ± 2.0	14.9	0.219	1.8
During rigorous training	4	25 ± n.d.	50.6 ± 3.2	19.8	0.391	2.8
In calorimeter	9	26 ± 3.3	52.4 ± 4.1	9.5	0.181	1.2
Runners during training	9	26 ± 3.3	51.6 ± 3.5	16.0	0.310	2.0
Cross-country skiers	4	25 ± 2.2	54.4 ± 5.1	24.8	0.456	2.8
Mountaineers[b]	2	37.5 ± 6.4	54.0 ± 1.4	16.2	0.301	2.0
Endurance runners	9	n.d. ± n.d.	55.3 ± 6.2	16.6	0.301	2.3
Male explorers[c]	2	38.2 ± 2.0	78.5 ± 9.2	44.8	0.570	4.5
Male soldiers						
Jungle training	4	22.5 ± 3.3	73.8 ± 8.9	27.3	0.369	2.7
Field training	14	27.1 ± 5.4	75.2 ± 5.7	19.7	0.262	1.9
Winter training	23	27.1 ± 3.8	79.8 ± 6.3	28.0	0.351	2.7
High mountain training	23	27.1 ± 3.8	79.8 ± 6.3	40.7	0.509	3.9
Base camp training	23	27.1 ± 3.8	79.8 ± 6.3	20.7	0.260	2.0
Active service	15	20 ± n.d.	70.7 ± 5.3	25.1	0.355	2.5
Arctic training	10	n.d. ± n.d.	77.0 ± 7.5	24.1	0.313	2.4

[a]Over the 21 days of the Tour de France.
[b]On Mount Everest.
[c]In the first 20 days of sled hauling across the Arctic by adults aged 35.3 and 41 years.
[d]Measured body weight.
[e]Total daily energy requirements (TDERs) were converted into physiological daily inhalation rates by the following equation: $TDER^{*}H^{*}(V_E/VO_2)^{*}10^{-3}$. H = 0.21 L of O_2/Kcal and $V_E/VO_2 = 27$ (Layton 1993). TDER = (TDEE + ECG).
TDEE = total daily energy expenditure. ECG = stored daily energy cost for growth. TDEEs were based on ^2H_2O and $H_2^{18}O$ disappearance rates from urine monitored by gaz-isotope-ratio mass spectrometry during 7 to 21-day periods (Black et al. 1996).
[f]Daily metabolic equivalent or daily BEE multiplier (TDER/BEE). BEEs or basal energy expenditures (BMRs expressed on a 24-hour basis) were measured by indirect calorimetry (Black et al. 1996).
Body mass index values, BEEs, TDEEs, ECGs, and TDERs are reported in Table Web-12, which is available on the Québec.
Ministry of Sustainable Development, Environment and Parks website (MDDEP 2006).
n = number of individuals; S.D. = standard deviation.

one age group (girls aged 1 to 2 years) whose kurtosis value is 1.73. Finally, means, standard deviations and percentile physiological daily inhalation rates for all subpopulations in normal and overweight/obese groups as well as comparison between female and male values were in all cases biologically consistent. Thus, assuming

Table 8. Distribution percentiles of physiological daily inhalation rates per unit of body weight (m^3/kg-day) for free-living normal-weight males and females aged 2.6 months to 96 years.

Gender and age group (years)	Observed p value[a]	Physiological daily inhalation rates[b] (m^3/kg-day)											DMET[d] (unitless)
			Percentile[c]										
		Mean ± S.D.	2.5nd	5th	10th	25th	50th	75th	90th	95th	97.5th	99th	Mean ± S.D.
Males													
0.22 to <0.5	0.823	0.509 ± 0.093	0.327	0.356	0.390	0.447	0.509	0.571	0.627	0.661	0.690	0.725	1.55 ± 0.28
0.5 to <1	0.302	0.479 ± 0.071	0.341	0.363	0.389	0.432	0.479	0.526	0.570	0.595	0.618	0.644	1.40 ± 0.22
1 to <2	0.706	0.480 ± 0.059	0.364	0.383	0.405	0.441	0.480	0.520	0.556	0.578	0.596	0.618	1.36 ± 0.22
2 to <5	0.304	0.444 ± 0.042	0.362	0.375	0.391	0.416	0.444	0.472	0.497	0.512	0.526	0.541	1.41 ± 0.16
5 to <7	0.037	0.415 ± 0.047	0.322	0.337	0.354	0.383	0.415	0.446	0.475	0.492	0.507	0.524	1.42 ± 0.15
7 to <11	0.525	0.372 ± 0.062	0.251	0.270	0.293	0.330	0.372	0.413	0.451	0.474	0.493	0.516	1.60 ± 0.23
11 to <23	0.986	0.300 ± 0.047	0.207	0.222	0.239	0.268	0.300	0.331	0.360	0.377	0.392	0.410	1.82 ± 0.22
23 to <30	0.348	0.247 ± 0.039	0.171	0.183	0.198	0.221	0.247	0.273	0.297	0.311	0.323	0.338	1.74 ± 0.24
30 to <40	0.030	0.237 ± 0.034	0.170	0.181	0.193	0.214	0.237	0.260	0.281	0.293	0.304	0.317	1.78 ± 0.21
40 to <65	0.649	0.230 ± 0.042	0.148	0.161	0.176	0.202	0.230	0.258	0.284	0.299	0.313	0.328	1.76 ± 0.27
65 to ≤96	0.967	0.188 ± 0.031	0.128	0.137	0.149	0.168	0.188	0.209	0.228	0.239	0.249	0.260	1.55 ± 0.25
Females													
0.22 to <0.5	0.011	0.504 ± 0.093	0.322	0.351	0.385	0.442	0.504	0.566	0.623	0.657	0.686	0.721	1.56 ± 0.29
0.5 to <1	0.371	0.463 ± 0.064	0.338	0.358	0.382	0.421	0.463	0.506	0.545	0.568	0.588	0.612	1.39 ± 0.21
1 to <2	0.007	0.451 ± 0.077	0.301	0.325	0.353	0.399	0.451	0.502	0.549	0.577	0.601	0.630	1.34 ± 0.25
2 to <5	0.274	0.441 ± 0.071	0.301	0.323	0.350	0.393	0.441	0.489	0.532	0.559	0.581	0.607	1.44 ± 0.26
5 to <7	0.037	0.395 ± 0.048	0.300	0.315	0.333	0.362	0.395	0.427	0.457	0.474	0.489	0.507	1.45 ± 0.18
7 to <11	0.148	0.352 ± 0.062	0.231	0.251	0.273	0.311	0.352	0.393	0.431	0.453	0.473	0.496	1.59 ± 0.24
11 to <23	0.190	0.269 ± 0.049	0.173	0.189	0.207	0.236	0.269	0.302	0.331	0.349	0.365	0.383	1.78 ± 0.29
23 to <30	0.004	0.233 ± 0.042	0.150	0.163	0.179	0.204	0.233	0.261	0.287	0.302	0.315	0.331	1.79 ± 0.29
30 to <40	0.395	0.235 ± 0.035	0.167	0.178	0.191	0.212	0.235	0.258	0.279	0.292	0.303	0.316	1.83 ± 0.26
40 to <65	0.482	0.211 ± 0.036	0.140	0.151	0.164	0.186	0.211	0.235	0.257	0.270	0.281	0.295	1.78 ± 0.27
65 to ≤96	0.010	0.172 ± 0.037	0.100	0.112	0.125	0.148	0.172	0.197	0.220	0.233	0.245	0.258	1.43 ± 0.30

[a] Observed p values based on Shapiro-Wilk normality tests. The number of individuals and measured body weights were gathered according to body mass index cut-offs and are given in Table 2.
[b] Total daily energy requirements (TDERs) reported in Table Web-4 (in kcal/kg-day) were converted into physiological daily inhalation rates by the following equation: $TDER^{*}H^{*}(V_E/VO_2)^{*}10^{-3}$. H = 0.21 L of O_2/Kcal and $V_E/VO_2 = 27$ (Layton 1993). TDER = (TDEE + ECG). TDEE = total daily energy expenditure. ECG = stored daily energy cost for growth. TDEEs in Table Web-3 were based on ^2H_2O and $H_2^{18}O$ disappearance rates from urine monitored by gaz-isotope-ratio mass spectrometry during 7- to 21-day periods for 1,252 individuals aged 2.6 months to 96 years (IOM 2002). ECGs from Table Web-1 were initially added to the basic TDEEs in order to obtain the appropriate TDERs.
[c] Percentiles based on a normal distribution assumption for all age groups.
[d] Daily metabolic equivalent or daily BEE multiplier (TDER/BEE). BEEs or basal energy expenditures (BMRs expressed on a 24-hour basis) were measured by indirect calorimetry (Table Web-3; IOM 2002). S.D. = standard deviation.
Tables Web-1, Web-3, and Web-4 are available on the Québec Ministry of Sustainable Development, Environment and Parks website (MDDEP 2006).

Table 9. Distribution percentiles of physiological daily inhalation rates (m^3/day-day) for free-living normal-weight and overweight/obese males aged 4 to 96 years.

Male and age group (years)	Observed p value[a]	Physiological daily inhalation rates[b] (m^3/kg-day) Mean ± S.D.	Percentile[c] 2.5nd	5th	10th	25th	50th	75th	90th	95th	97.5th	99th	DMET[d] (unitless) Mean ± S.D.
Normal-weight													
4 to <5.1	0.132	0.418 ± 0.044	0.333	0.346	0.362	0.389	0.418	0.448	0.474	0.490	0.504	0.520	1.41 ± 0.13
5.1 to <9.1	0.855	0.408 ± 0.057	0.296	0.314	0.335	0.369	0.408	0.446	0.481	0.502	0.520	0.540	1.52 ± 0.21
9.1 to <18.1	0.834	0.334 ± 0.048	0.240	0.255	0.272	0.302	0.334	0.366	0.395	0.413	0.428	0.445	1.68 ± 0.25
18.1 to <40.1	0.073	0.245 ± 0.037	0.173	0.184	0.198	0.220	0.245	0.270	0.292	0.306	0.317	0.331	1.79 ± 0.22
40.1 to <70.1	0.248	0.222 ± 0.040	0.143	0.155	0.170	0.195	0.222	0.249	0.274	0.289	0.301	0.316	1.68 ± 0.25
70.1 to ≤96	0.966	0.185 ± 0.032	0.122	0.132	0.144	0.163	0.185	0.206	0.226	0.237	0.247	0.259	1.52 ± 0.27
Overweight/obese													
4 to <5.1	0.407	0.367 ± 0.044	0.281	0.295	0.310	0.337	0.367	0.396	0.423	0.439	0.453	0.469	1.44 ± 0.14
5.1 to <9.1	0.002	0.345 ± 0.078	0.193	0.218	0.246	0.293	0.345	0.398	0.445	0.473	0.498	0.526	1.54 ± 0.29
9.1 to <18.1	0.755	0.265 ± 0.039	0.188	0.201	0.215	0.239	0.265	0.292	0.316	0.330	0.342	0.357	1.58 ± 0.17
18.1 to <40.1	0.577	0.213 ± 0.036	0.142	0.154	0.167	0.189	0.213	0.237	0.259	0.272	0.284	0.297	1.84 ± 0.27
40.1 to <70.1	0.053	0.194 ± 0.034	0.127	0.138	0.150	0.171	0.194	0.217	0.238	0.250	0.261	0.274	1.77 ± 0.29
70.1 to ≤96	0.504	0.173 ± 0.030	0.114	0.123	0.134	0.153	0.173	0.194	0.212	0.223	0.233	0.244	1.52 ± 0.28

[a]Observed p values based on Shapiro-Wilk normality tests. The number of individuals and measured body weight for normal-weight and overweight/obese males were gathered according to body mass index (BMI) cut-offs and are given in Table 3. BMIs for sub-groups are reported in Table Web-6.

[b]Total daily energy requirements (TDERs) reported in Table Web-6 (in kcal/kg-day) were converted into physiological daily inhalation rates by the following equation: $TDER^{*}H^{*}(V_E/VO_2)^{*}10^{-3}$. H = 0.21 L of O_2/Kcal and $V_E/VO_2 = 27$ (Layton 1993). TDER = (TDEE + ECG). TDEE = total daily energy expenditure (Table Web-5).

ECG = stored daily energy cost for growth (Table Web-6). TDEEs were based on ^2H_2O and $H_2^{18}O$ disappearance rates from urine monitored by gaz-isotope-ratio mass spectrometry during 7- to 21-day periods for 627 males aged 4 to 96 years (IOM 2002). ECGs from Table Web-1 were initially added to the basic TDEEs in order to obtain the TDER values.

[c]Percentiles based on a normal distribution assumption for all age groups.

[d]Daily metabolic equivalent or daily BEE multiplier (TDER/BEE). BEEs or basal energy expenditures (BMRs expressed on a 24-hour basis) were measured by indirect calorimetry (Table Web-5; IOM 2002).

Tables Web-1, Web-5, and Web-6 are available on the Québec Ministry of Sustainable Development, Environment and Parks website (MDDEP 2006).

Table 10. Distribution percentiles of physiological daily inhalation rates (m^3/day-day) for free-living normal-weight and overweight/obese females aged 4 to 96 years.

Female and age group (years)	Observed p value[a]	Physiological daily inhalation rates[b] (m^3/kg-day)											DMET[d] (unitless)
			Percentile[c]										
		Mean ± S.D.	2.5nd	5th	10th	25th	50th	75th	90th	95th	97.5th	99th	Mean ± S.D.
Normal-weight													
4 to <5.1	0.387	0.397 ± 0.048	0.304	0.319	0.336	0.365	0.397	0.430	0.459	0.476	0.491	0.508	1.42 ± 0.17
5.1 to <9.1	0.086	0.372 ± 0.062	0.251	0.271	0.293	0.331	0.372	0.414	0.451	0.474	0.493	0.516	1.58 ± 0.24
9.1 to <18.1	0.300	0.290 ± 0.057	0.178	0.196	0.217	0.251	0.290	0.328	0.363	0.383	0.401	0.422	1.69 ± 0.30
18.1 to <40.1	0.008	0.234 ± 0.038	0.160	0.172	0.186	0.209	0.234	0.260	0.283	0.296	0.308	0.322	1.81 ± 0.27
40.1 to <70.1	0.312	0.203 ± 0.038	0.128	0.140	0.154	0.177	0.203	0.229	0.252	0.266	0.278	0.292	1.72 ± 0.30
70.1 to ≤96	0.003	0.163 ± 0.035	0.095	0.106	0.119	0.140	0.163	0.187	0.208	0.221	0.232	0.244	1.33 ± 0.27
Overweight/obese													
4 to <5.1	0.780	0.340 ± 0.044	0.254	0.268	0.284	0.310	0.340	0.370	0.396	0.412	0.426	0.442	1.42 ± 0.14
5.1 to <9.1	0.215	0.316 ± 0.067	0.185	0.207	0.231	0.271	0.316	0.361	0.402	0.426	0.447	0.472	1.56 ± 0.28
9.1 to <18.1	0.172	0.247 ± 0.049	0.151	0.167	0.184	0.214	0.247	0.280	0.309	0.327	0.342	0.360	1.72 ± 0.32
18.1 to <40.1	0.834	0.189 ± 0.027	0.135	0.144	0.154	0.170	0.189	0.207	0.224	0.234	0.243	0.253	1.78 ± 0.23
40.1 to <70.1	0.713	0.162 ± 0.030	0.102	0.112	0.123	0.141	0.162	0.182	0.201	0.212	0.221	0.232	1.62 ± 0.26
70.1 to ≤96	0.578	0.145 ± 0.025	0.096	0.104	0.113	0.128	0.145	0.163	0.178	0.187	0.195	0.205	1.41 ± 0.24

[a]Observed p values based on Shapiro-Wilk normality tests. The number of individuals and measured body weight for normal-weight and overweight/obese females were gathered according to body mass index (BMI) cut-offs and are given in Table 4. BMIs for sub-groups are reported in Table Web-8.

[b]Total daily energy requirements (TDERs) reported in Table Web-8 (in kcal/kg-day) were converted into physiological daily inhalation rates by the following equation: $TDER^{*}H^{*}(V_E/VO_2)^{*}10^{-3}$. H = 0.21 L of O_2/Kcal and $V_E/VO_2 = 27$ (Layton 1993). TDER = (TDEE + ECG). TDEE = total daily energy expenditure (Table Web-7).

ECG = stored daily energy cost for growth (Table Web-8). TDEEs were based on ^2H_2O and $H_2^{18}O$ disappearance rates from urine monitored by gaz-isotope-ratio mass spectrometry during 7- to 21-day periods for 982 females aged 4 to 96 years (IOM 2002). ECGs from Table Web-1 were initially added to the basic TDEEs in order to obtain the TDER values.

[c]Percentiles based on a normal distribution assumption for all age groups.

[d]Daily metabolic equivalent or daily BEE multiplier (TDER/BEE). BEEs or basal energy expenditures (BMRs expressed on a 24-hour basis) were measured by indirect calorimetry (Table Web-7; IOM 2002).

Tables Web-1, Web-7, and Web-8 are available on the Québec Ministry of Sustainable Development, Environment and Parks website (MDDEP 2006).

normality for all sub-populations or age groups was statistically justified (Tables 2–4, 8–10).

DISCUSSION

TDERs and physiological daily inhalation rates clearly show a decrease as a function of age from birth to adulthood (Tables Web-2 and Web-4). When children from normal-weight groups reach 11 years of age, the TDER sharply drops by 12.7 kcal/kg-day for boys and 14.6 kcal/kg-day for girls (−19.4% and −23.6%, respectively). This is a clear deceleration compared to the decrease rate in younger children (Table Web-4). Similarly sharp TDER decelerations are shown in overweight/obese groups dropping by 14.2 kcal/kg-day for boys and 12.3 kcal/kg-day for girls once they exceeded 9 years of age (Tables Web-6 and Web-8). Such pattern is consistent with the remarkable increase in alveoli number and pulmonary gas-exchange surfaces from birth to about 8 years old, which ensures higher CO_2 and O_2 exchanges per unit of body weight for lower minute ventilation; the number of alveoli still increases very slowly beyond 8 years of age, whereas the size of alveolar structures grows linearly throughout early adolescence (Polgar and Weng 1979).

Physiological daily inhalation rates in m^3/kg-day drop by about 66 to 76% within the course of a lifetime (Tables 1 and 8). Rates for normal-weight and overweight/obese children aged 4 to 5 years (n = 269) are between 1.5 and 2.7 times higher than values for normal active adults aged 18 to 96 years (Tables 9 and 10; n = 768). Nevertheless, as measured by Prentice *et al.* (1996) with adult subjects (n = 319) using the DLW method, despite the fact that overweight/obese individuals (n = 679) are inhaling between 0.8 to 3.0 m^3 more air per day than normal-weight individuals (Tables 3 and 4), their physiological daily inhalation rates are 6 to 21% lower than that of their leaner counterparts (n = 930) when expressed in m^3/kg-day (Tables 9 and 10). Consequently, healthy newborns aged 3 to 5 weeks and normal-weight infants aged 2.6 months to less than 6 months (n = 118) inhale more air per unit of body weight (0.504 to 0.739 m^3/kg-day) than any overweight/obese or older normal-weight individual with normal active life styles (n = 1846). Their physiological daily inhalation rates (Tables 1 and 8) are also higher than those for underweight adult females with anorexia nervosa (Table 6; 0.244 to 0.382 m^3/kg-day n = 17) and also greater than 87% of those for athletes, explorers, soldiers, and adults from less affluent societies (Tables 5 and 7; 0.181 to 0.456 m^3/kg-day, n = 187). As underlined by Black *et al.* (1996), daily inhalation rates for other (13%) extremely active individuals during short term periods (0.512 to 0.672 m^3/kg-day, n = 33) are expected to be lower when based on a basis of whole-year average, considering that such physical requirements (DMET > 4) are not sustainable as a permanent way of life.

Physiological daily inhalation rates for newborns and normal-weight infants aged 2.6 to less than 6 months are 2.1 to 5.1 times higher than those of normal-weight and overweight/obese adults aged 18 to 96 years with normal active life styles (Tables 1 and 8–10). These inhalation rates are also higher than the highest mean values that have been calculated by Brochu *et al.* (2006b) for pregnant and lactating teenage girls and women aged 11 to 55 years (n = 357), based on DLW measurements (0.385 ± 0.110 and 0.383 ± 0.064 m^3/kg-day, respectively). The 99th percentile physiological daily inhalation rates of 0.721 and 0.725 m^3/kg-day for normal-weight girls and boys aged 2.6 to less than 6 months, respectively, are higher than the highest percentile of 0.622 m^3/kg-day in gravid females and 0.647 m^3/kg-day in breastfeeding females that have been determined in Brochu *et al.* (2006b). The high daily inhalation values for newborns are consistent with their DMETs (Table 1). Mean values of 1.89 and 2.11 for newborns aged 1 month are as high as those for some female athletes (mountaineers, swimmers, runners during training) and male soldiers during base camp and field training (Tables 1 and 7). However, newborns aged 3 weeks show a higher mean DMET value reaching 2.77, which is as high as those for most male and female athletes (mountaineers, swimmers, cross-country skiers, runners during training, endurance runners) and male soldiers during almost all types of demanding training including jungle, winter, and Arctic training (Tables 1 and 7).

Over the last 20 years, the results of factorial and physiological studies on 24-hour daily inhalation rates have raised the question of adequate values for the determination of air quality criteria and the setting of standard values. For example, Health Canada (1996) uses a daily inhalation rate of 0.444 m^3/kg-day to calculate the tolerable daily intake by inhalation of non-carcinogenic chemicals (*i.e.*, 12 m^3/day for 27 kg, for children aged 5 to 11 years). This compares to the daily inhalation estimate of 0.286 m^3/kg-day, which has been published by the Federal Register in 1980 and is still used by many scientists (*i.e.*, 20 m^3/day for a 70-kg adult). Health Canada (1996) was first to calculate the tolerable daily intake for non-carcinogenic compounds using inhalation rates for children. However, based on the present physiological values, the rate of 0.444 m^3/kg-day is adequate for boys aged 2 to less than 5 years but not for children 5 to 11 years of age (Table 8). On the other hand, newborns aged 3 weeks to 1 month as well as more than 75% of children aged 2.6 months to less than 11 years inhale more toxic chemicals than associated safe doses which are not anticipated to result in any adverse effects in humans, when air concentration reaches the air quality criteria and standard values determined by using the rate of 0.286 m^3/kg-day from the Federal Register (Tables 1 and 8). Moreover, the upper 99th percentile value of 0.725 m^3/kg-day in Table 8 would be more appropriate as a default value than the rate of 0.59 m^3/kg-day (single value of Layton for infants aged less than 1 year) selected by the Department of Pesticide Regulation in California to represent all children in health risk assessment when duration of activity and activity pattern are not specified (USEPA 2000).

Among the numerous physiological daily inhalation rates given in the present article, only a few will have an important health risk assessment utility for Canadian and American populations. For instance, only 2% of Canadian adults were underweight in 1996–1997 (Gilmore 1999). In addition, athletes and explorers constitute an exceptional small sample of the population. However, Canadian and American populations include a large percentage of overweight/obese individuals. For example, 46% of Canadian adults in 1996–1997 and 65% of their American counterparts in 1999–2000 were overweight or obese (Gilmore 1999; NCHS 2003; Willms *et al.* 2003). Considering the fact that healthy normal-weight individuals inhale larger volumes of air per kg of weight than their overweight/obese counterparts, daily inhalation values expressed in m^3/kg-day for the former will provide adequate protection in health risk assessment for the latter. However, inhalation data given in the present article compared with those in Brochu *et al.* (2006b) yield to the conclusion that physiological daily inhalation rates for under-, normal-, and overweight/obese pregnant and lactating females in m^3/day and m^3/kg-day are higher than those for males. For instance, in normal-weight subjects, females are susceptible to higher intakes of air pollutants by the respiratory tract than males by 18 to 41% throughout pregnancy and 23 to 39% during postpartum weeks. Therefore, the distribution of physiological daily inhalation rates presented in Brochu *et al.* (2006b) is recommended for health risk assessment for gravid and breast-feeding females. Finally, considering that males inhale more air per unit of body weight than non-gravid and non-lactating females, the distribution of physiological daily inhalation rates given in the present article for healthy normal-weight males are appropriate for used in health risk assessment ($p \geq 0.03$) to ensure the protection of all individuals other than pregnant and lactating females for both the Canadian and American populations.

CONCLUSION

We recommend that the 99th percentile physiological daily inhalation rate of 0.725 m^3/kg-day for normal-weight boys aged 2.6 to less than 6 months be set for air quality criteria and standard calculations for non-carcinogenic compounds ($p \geq 0.05$ based on the Shapiro-Wilk normality test). This will ensure that less than 1% of infants aged 2.6 to less than 6 months and of course no older individual up to 96 years old with normal active life styles (including pregnant and lactating females as well as overweight/obese individuals) inhale more toxic chemicals than associated previously mentioned safe doses, when air concentration reaches the resulting air quality criteria and standard values. Using this physiological rate, criteria and standard values might be protective for most newborns aged 1 month and younger, considering their mean physiological daily inhalation rates.

Newborns are less exposed to outdoor environmental air contaminants than older individuals. Nevertheless, because they have smaller pseudoalveolar structures, hence smaller gas exchange pulmonary surfaces, newborns do breathe larger volumes of air than older individuals to be sufficiently oxygenated. Thus, a temporary slightly higher physiological daily inhalation rate of 0.956 m^3/kg-day is recommended for short-term criteria and standard calculations for toxic chemicals that yield adverse effects over short exposure periods (instantaneous to short-term duration). The latter rate corresponds to the estimated 99th percentile of the physiological daily inhalation rate based on the mean TDER and physiological daily inhalation values for newborns aged 21 days, assuming normality (130.4 $\pm$ 16.4 kcal/kg-day and 0.739 $\pm$ 0.093 m^3/kg-day, respectively). This rate is recommended temporarily, until more TDER values are measured with the DLW method and for a larger number of newborn subjects. Future studies on physiological daily inhalation rates for individuals with pre-existing medical conditions rendering a greater susceptibility to toxicants are however recommended because this aspect has not been covered in the present article.

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